NZS 4431:1989

Code of practice for
EARTH FILL FOR RESIDENTIAL DEVELOPMENT

1989 edition of NZS 4431:1978
Incorporating Amendment 1 to the 1978 edition, and
appending Amendment 1 to the 1989 edition

Single User PDF Terms & Conditions

You have material which is subject to strict conditions of use. Copyright in this material is owned by the New Zealand Standards Executive. Please read these terms and conditions carefully, as in addition to the usual range of civil remedies available to Standards New Zealand on behalf of the New Zealand Standards Executive for infringement of copyright, under New Zealand law every person who infringes copyright may be liable to a fine of up to $10,000 for every infringing copy or imprisonment of up to 5 years, or a fine of up to $150,000 or imprisonment not exceeding 5 years.

You have access to a single-user licence to read this non-revisable Adobe Acrobat PDF file and print out and retain ONE printed copy only.

We retain title and ownership of the copyright in this PDF file and the corresponding permitted printed copy at all times.

Under this license use of both the PDF file and the single permitted printed copy of this PDF file you may make are restricted to you. Under no circumstances are you permitted to save, sell, transfer, or copy this PDF file, the one permitted printed copy of this PDF file, or any part of either of them.

You undertake that you will not modify, adapt, translate, reverse engineer, decompile, disassemble or create derivative works based on any of the downloaded PDF file, nor will you merge it with any other software or document, even for internal use within your organization.

Under no circumstances may this PDF file be placed on a network of any sort without our express permission.

You are solely responsible for the selection of this PDF file and any advice or recommendation given by us about any aspect of this PDF file is intended for guidance only and is followed or acted upon entirely at your own risk.

We are not aware of any inherent risk of viruses in this PDF file at the time that it is accessed. We have exercised due diligence to ensure, so far as practicable, that this file does not contain such viruses.

No warranty of any form is given by us or by any party associated with us with regard to this PDF file, and you accept and acknowledge that we will not be liable in any way to you or any to other person in respect of any loss or damage however caused which may be suffered or incurred or which may arise directly or indirectly through any use of this PDF file.

Regardless of where you were when you received this PDF file you accept and acknowledge that to the fullest extent possible you submit to New Zealand law with regard to this licence and to your use of this PDF file.

CONTENTS **PAGE**

RELATED DOCUMENTS

Reference is made in this document to the following:

NEW ZEALAND STANDARDS		Clause reference herein
NZS 1900:------	Model building bylaw	1.1, 1.2,
NZS 4203:1984	General structural design and design loadings for buildings	1.1
NZS 4402:------	Methods of testing soils for civil engineering purposes	
Test 2.1:1986	Determination of the water content	11.1.1, 11.2.1,
Test 2.2:1986	Determination of the liquid limit	11.3.1
Test 2.3:1986	Determination of the plastic limit	11.4.1
Test 2.4:1986	Determination of the plasticity index	11.5.1
2.7:------	Determination of the solid density of soil particles	
Test 2.7.1:1986	Method for coarse, medium and fine soils	11.11.1
Test 2.7.2:1986	Method for medium and fine soils	11.11.1
2.8:------	Determination of the particle-size distribution	
Test 2.8.1:1986	Standard method by wet sieving	11.6.1
Test 2.8.2:1986	Subsidiary method by dry sieving	11.6.1
Test 2.8.3:1986	Standard method for fine soils (pipette method)	11.6.1
Test 2.8.4:1986	Subsidiary method for fine soils (hydrometer method)	11.6.1
4.1:------	Determination of the dry density water content relationship	
Test 4.1.1:1986	NZ standard compaction test	11.8.1
Test 4.1.3:1986	NZ vibrating hammer compaction test	11.9.1
4.2:------	Determination of the minimum and maximum dry densities and relative density of a cohesionless soils	
Test 4.2.3:1988	Relative density	11.10.1
5.1:------	Determination of the density of soil	
Test 5.1.1:1986	Sand replacement method for the determination of the *in situ* density	11.7.1
Test 5.1.2:1986	Balloon densometer method for the determination of the *in situ* density	11.7.1
Test 5.1.3:1986	Sampling tube method for the determination of *in situ* density	11.7.1
Test 5.1.4:1986	Immersion in water method	11.7.1
Test 5.1.5:1986	Water displacement method	11.7.1
6.1:------	Determination of the California Bearing Ratio (CBR)	
Test 6.1.3:1986	Standard method for *in situ* tests	7.4.3.1
6.4:------	Determination of the shear strength of a soil	
*Test 6.4.2:-----	Hand held shear vane method	11.12.1
6.5:------	Determination of the penetration resistance of a soil	
Test 6.5.2:1988	Hand method using a dynamic cone penetrometer	7.4.3.1
Test 6.5.3:1988	Cone penetration resistance using a cone or a friction cone	7.4.3.1

*In preparation

NEW ZEALAND LEGISLATION

Engineers Registration Act 1924	3.1, App. A
Water and Soil Conservation Act 1967	8.4.1

OTHER PUBLICATIONS

Factors that influence field compaction of soil. U.S. Highway Research Board Bulletin 272	11.2.1

Further recommendations relating to earth fill and land drainage are contained in the following:

NEW ZEALAND STANDARD

NZS 4404:1981 Code of practice for urban land subdivision

FOREWORD

With the increasing use of mass earth fills to produce suitably shaped landforms for residential developments various sections of the community and public authorities require assurance that the man-made landforms are of comparable stability to natural landforms, and are so constructed as to minimize the possibility of damage to property occurring through ground movement in the form of slips, subsidence, creep, or erosion, whether due to the nature of the fill itself or whether due to the nature of the underlying strata. This Standard describes practices to be adopted in the planning, execution, inspection, and control of earth fills for residential subdivisional developments in order to minimize damage being sustained by buildings and services through subsequent ground movements.

The principal purposes of this Standard are as follows:

(a) To provide a means of making a valid assessment of the general suitability of a site for building purposes. Compliance with this Standard does not remove the necessity for the normal inspection and design of foundations as would be made in natural ground.

(b) To provide guidance for agencies engaged in planning, designing and supervising earth fills for residential developments.

(c) To provide a code of practice that can be cited by local authorities as a means of compliance with bylaw requirements -

   (i) For the quality and safety of earth fills for residential subdivisions; and
   (ii) For the subsequent issue of building permits for proposed buildings in areas which have been subjected to earth fill.

The satisfactory construction of earth fills depends upon the use of orderly and systematic procedures of site preparation and earth moving, which can be supervised without confusion. The achievement of a uniform standard of strength and compressibility is at least as important as the high quantitative standards expressed by test results.

Tests of compaction standards achieved must be complemented by regular inspection by experienced personnel.

This edition of the Standard incorporates Amendment No. 1 to the 1978 edition.

Changes have been made as a result of suggestions by users of the Standard for improvements. References to test methods are more precise following the publication of NZS 4402:1986, *Methods of testing soils for civil engineering purposes*, and Supplement No. 1:1988 to that Standard.

These changes to the 1978 edition are marked by a vertical line in the margin.

NEW ZEALAND STANDARD

Code of practice for EARTH FILL FOR RESIDENTIAL DEVELOPMENT

1 SCOPE

1.1
This Standard sets out earth fill practices which experience has shown to produce fills of satisfactory stability for:

(a) Residential construction involving one-storey and two-storey timber framed buildings, or masonry buildings, or buildings of both timber and masonry not requiring specific design in terms of NZS 1900* provided that:

(i) Continuous brittle walls such as masonry veneer and stucco, especially those which may be subject to differential settlement, may require specific design of foundations;

(ii) The foundation sections of the relevant non-design Codes are observed and complied with;

(iii) That the floor loads used do not exceed 1.5 kPa, which corresponds to the floor live load specified for domestic buildings (excluding balconies) by NZS 4203;

(iv) Any "special limitations" noted on the certificate contained in Appendix A are complied with.

(b) Residential services and streetworks.

1.2
This Standard is approved as a means of compliance with the relevant requirements of NZS 1900.

1.3
The following aspects are *not* covered by this Standard:

(a) Cuts;

(b) Methods of evaluation of the suitability of existing natural ground for founding houses and services;

(c) Methods of evaluation of the suitability of filled ground for founding houses and services where the methods and standards of filling have not been controlled in terms of this Standard;

(d) Requirements for retaining wall construction and backfilling;

(e) Contractual aspects of earth fills.

2 INTERPRETATION

2.1
In this Standard the word "shall" indicates a requirement that is to be adopted in order to comply with the Standard whereas the word "should" indicates a recommended practice.

3 DEFINITIONS

3.1
In this Standard, unless inconsistent with the context, the following definitions apply:

GROUND is a general term used to describe the material in the vicinity of the surface of the earth, whether soil or rock.

INSPECTING ENGINEER means a professional engineer experienced in earthworks duly registered under the provisions of the Engineers Registration Act 1924 and who is the holder of a current annual practising certificate; who signs and submits a report to the owner or developer of the land at the time of construction of the earth fill as to the compliance of the earth fill with this Standard.

POST - CONSTRUCTION SETTLEMENT means the ground settlement that takes place after commencement of construction of buildings or services.

SOIL means the heterogeneous aggregation of particles comprising either peats, clays, silts, sands, gravels, crushed and re-oriented rock fragments, or a mixture of any of the above. The term excludes rock, that is, intact rock masses, whether highly jointed or not.

COHESIONLESS SOIL means a soil where the attractive forces between soil particles are derived almost entirely from interlocking forces between soil grains. It is generally found that where 85 % or more by weight of the soil has a grain size in excess of 75 µm, the material can be regarded as being cohesionless. Such soils have no plasticity or cohesion and generally (but not always) do not have a well-defined optimum water content when tested in accordance with 11.8.1.

COHESIVE SOIL means a soil where the attractive forces between soil particles are derived only partly from interlocking forces between soil grains. Such soils exhibit plasticity and cohesion; they have a liquid limit (*see* 11.3.1) in excess of 20 %, and generally exhibit a well defined optimum water content when tested in accordance with 11.8.1.

SOFT SOIL means soil having a high clay or silt or organic content, and having a low shear strength.

STABLE FILL means earth fill constructed in a manner which should allow buildings or services or both to be founded on it without subsequent detrimental movement.

4 TECHNICAL RESPONSIBILITIES

4.1 Inspecting engineer

4.1.1
Where any proposed subdivision involves the construction of earth fills on any part of a proposed housing lot, then an inspecting engineer, as defined in section 3, shall be engaged to carry out the following functions:

(a) Before work commences or during construction, to determine whether further specialist services such as geological or soil engineering services are required to achieve satisfactory performance of the earth fills;

(b) Before work commences, to prepare or approve the drawings and specification defining the earth fill;

(c) During construction to ensure that regular inspection is provided. While a daily visit might be regarded as a reasonable minimum during earthwork construction on minor projects, inspection on a near full-time basis is often necessary;

(d) During construction, to determine the methods and frequency of construction control tests to be carried out, determine the reliability of the testing and to evaluate the significance of test results and of his inspectors' reports in assessing the quality of the finished work;

(e) On completion, to submit a report (as set out in 10.2) as to the compliance of the earthworks with this Standard.

4.1.2
The inspecting engineer may assume in addition the function of the inspector (*see* 4.2). He may also assume the function of the testing agency (*see* 4.3) if he has the necessary equipment and experience in laboratory testing procedures. He may also assume the functions of a specialist soils engineer (*see* 4.4) if he possesses suitable qualifications and experience.

4.2 Inspector

4.2.1
An inspector appointed to supervise the quality of earth fill construction shall be responsible directly to, and shall act on behalf of, the inspecting engineer.

4.3 Testing agency

4.3.1
Investigation testing and construction control testing shall be carried out by an agency whose testing competence is approved by the inspecting engineer.

4.4 Specialist consultants

4.4.1
Where the inspecting engineer considers it necessary, he should obtain advice from a specialist soils engineer or geologist.

5 SITE INVESTIGATION

5.1 Preliminary study

5.1.1
In preparing a general arrangement of a subdivision the general nature and shape of the ground should be studied and particular note taken of:

(a) The geological nature and distribution of soils and rock;

(b) Existing and proposed drainage conditions and the likely effects on groundwater;

(c) Previous history of ground movements in similar soils in the area; and

(d) Performance of comparable earth fills (if any) in adjacent areas.

5.2 Detailed subsurface investigation and testing

5.2.1
Soil data shall be obtained for areas which:

(a) Are intended to form *in situ* bases for stable fills; or

(b) Are intended to yield material for construction of stable fills (excavated permanent batters are not covered by this Standard).

5.2.2
Sufficient borings, probings, or open cuts should be made to:

(a) Classify the soil strata by field and visual methods; and

(b) Establish the extent and variation in depths of the principal soil types.

5.2.3
The soil information thus obtained shall form the basis for;

(a) Further sampling and testing which may be required on representative soil types; and

(b) Relating subsequent soil test properties to relevant strata over the site.

5.3 Sampling and testing

5.3.1
The test data appropriate in different areas may include:

(a) Areas of soft or loose soil which it is intended to leave beneath any depth of fill:
Liquid and plastic limits, natural water content, consolidation and shear strength, sensitivity characteristics, and relative density of loose sand;

(b) Areas to be covered by deep fillings:
Liquid and plastic limits, and natural water content. Where these properties indicate the likelihood of settlement or slumping of the proposed fillings, consolidation and shear strength and sensitivity characteristics should be determined;

(c) Areas where natural surface or subsurface drainage will be extensively altered or reversed:
Liquid and plastic limits, natural water content, shrink/swell characteristics, organic content, and the position of the natural groundwater table;

(d) Areas from which material for stable fillings will be obtained:
Natural moisture content and compaction characteristics (optimum water content and maximum dry density). Liquid and plastic limits should be determined on materials that indicate plasticity. Solid density of the soil particles should be determined in cases where a shear strength and air voids control method is to be used (see 7.4.2.3).

6 ENGINEERING CRITERIA

6.1 Stability criteria

6.1.1 *Settlement*

6.1.1.1
The most important factor in ensuring satisfactory performance of stable fills is the limiting of post-construction differential settlements. The design and construction of fills should be such that these settlements are kept within acceptable limits.

6.1.1.2
The effect of settlement of the fill caused by its own weight can be reduced by allowing a lapse of time between site filling and commencement of building.

NOTE - There is, at present, a lack of well-documented data to demonstrate what upper limits can be tolerated, and there is a wide range of opinion as to what limits should be set. Relatively small differential movements will cause unsightly cracking of masonry and masonry veneer but this is not necessarily of any structural significance. The same movements may not be noticed in a weatherboard house.

6.1.1.3
The weight of residential buildings of one-storey and two-storey construction, not requiring specific design in terms of NZS 1900, is unlikely to produce significant settlement of fill constructed in accordance with this Code.

6.1.1.4
Local filling placed close to a house during or after construction (for example for patios) will produce much larger loads which can induce differential settlement of the house.

6.1.2 *Bearing capacity*

6.1.2.1 *House areas*

6.1.2.1.1
The strength of the ground resisting general shear failure (and resulting gross deformation) under the footings of a house is a local phenomenon, distinct from settlement as considered in 6.1.1.

6.1.2.1.2
Generally speaking, fill constructed to minimize settlement in accordance with this Code will have adequate shear strength. It should be noted that it may be impracticable to provide sufficient supervision of construction to be sure that localized soft areas do not occur in the upper layers of the fill within the zone of influence of small foundations.

6.1.2.1.3
Should the routine foundation's inspection by the builder or the local authority during construction suggest, or should the inspecting engineer suspect, that localized soft areas are present, then tests shall be made to determine the required treatment of the fill material, or of the foundations. These tests should extend to a depth below the footings of not less than twice the width of the footings or 1.2 m (whichever is the greater) and may include shear strength tests, field load tests or dynamic penetrometer or other recognized soil strength tests.

6.1.2.2
Streetworks areas
The pavement thickness requirements or the adequacy of compaction of the subgrade for streetworks, or both should be finally confirmed by tests acceptable to the local authority on the finished subgrade.

6.1.3
Shrinkage and expansion

6.1.3.1
Because expansive clay soils are likely to undergo shrinkage and swelling when subjected to seasonal or other changes in water content, special examination of swelling and shrinkage characteristics shall be made in the case of highly plastic soils.

6.1.3.2
Where applicable, a foundation depth or design sufficient to minimize these effects, particularly for continuous brittle walls, may be noted on the certificate (see section 7).

6.1.4
Slope stability

6.1.4.1
In many cases, it is impracticable to measure quantitatively the factor of safety against shear failure, but the maximum slopes of fills may be determined by the inspecting engineer by observation of slopes of fills which have a longstanding history of stability and which consist of similar material in similar geological groundwater and drainage conditions. The observed slope should be of a similar height to the proposed slope.

6.1.4.2
Where close precedent is not available, a special soil engineering investigation of fills should be carried out to determine the degree of slope or maximum height or both. In the assessment of stability of slopes, account should be taken of possible future changes in subsurface seepage conditions and of the effects of earthquake.

6.2
Provision for permanent services

6.2.1
All service pipes installed under earth filling should be flexible, or flexibly joined, so that they may deflect without breaking if the fill settles.

6.2.2
Sewers

6.2.2.1
All sewers in fills shall be sealed effectively to prevent seepage from the sewer into the ground. No sewage treatment plant shall discharge effluent into a fill whereby the stability of the fill might be impaired.

6.2.3
Drainage

6.2.3.1
Stormwater structures, pipes, and culverts installed in fills shall be designed and constructed to ensure adequate capacity, strength, and watertightness to prevent leakage into the fill through blockage, running under pressure, or structural failure.

6.2.4
Subsoil drainage

6.2.4.1
Before fill is constructed over natural ground, pervious drains or similar subsoil seepage control systems should be installed to lead seepage away from all springs or potential areas of seepage emission from natural ground into fill, in order to:

(a) Prevent saturation of the fill before construction of the fill is complete (prior saturation can delay settlement of the fill);

(b) Prevent internal erosion ("piping"); and

(c) Prevent internal seepage pressures which reduce shear strength.

6.2.4.2
Subsoil drains shall discharge via flexible jointed pipes to a destination approved by the local authority, preferably to stable watercourses or to piped stormwater systems.

6.2.4.3
A record shall be kept of the position, type and size of all subsoil drains, and in particular, the position of their outlets.

6.2.4.4
Where seepage is encountered from a sloping natural ground abutting a fill, a bench shall be cut just below the line of seepage and drains installed

to collect the seepage and discharge it clear of the fill to a destination approved by the local authority, preferably to a stable watercourse or a piped stormwater system.

6.2.5
Run-off drainage

6.2.5.1
Long-term control of surface run-off water shall be designed to:

(a) Minimize erosion of the ground surface; and

(b) Prevent internal instability through excessive ingress of surface water into the soil.

6.2.5.2
Where surface water could cause erosion of batters, an interceptor drain should be provided above the top of the batter; special precautions will be necessary with pumice and similar soils. Open interceptor drains shall be constructed in permanent materials to minimize erosion, and shall lead stormwater into a destination, preferably a stable watercourse or piped stormwater system, approved by the local authority.

6.2.5.3
Where final batters are constructed to a benched shape, the benches should be sloped back and graded longitudinally to reduce spillage of stormwater down the batter. Run-off emerging from the end of a bench should be dispersed to existing well vegetated slopes clear of the sides of the fill or discharged via a non-erodible channel or pipe into a stable water course.

6.2.5.4
To prevent internal saturation and instability of fills, provision should be made to prevent water from stormwater systems from flowing into a fill, or into natural ground near the toe or sides of a fill.

6.2.5.5
Stormwater soak-pits shall not be permitted to be constructed in a fill whereby the stability of the fill might be impaired.

6.3
Surface protection of batters

6.3.1
Batters shall be provided with sufficient surface protection to minimize erosion from rainfall run-off, wind, and fretting under climatic conditions.

6.3.2
Methods of batter protection include permanent and temporary mulches with or without seeding to grass, shrubs or trees, the direct planting of vegetation, or other protective surfacing.

6.3.3
Surface protection may be included as the fill is being constructed and shall be completed as soon as practicable after construction of the batter.

7 QUALITY OF FILLING MATERIAL

7.1
Soil type

7.1.1
Material used as a filling shall be identifiable as a soil type whose general properties have been determined and confirmed by engineering testing and investigation as being suitable for fill material. The following criteria shall be established:

(a) Soil water content limits during compaction (see 7.3);

(b) Dry density to be achieved by compaction (see 7.4); and

(c) Such other criteria (for example, maximum percentage air voids or minimum shear strength) as the inspecting engineer may specify.

7.1.2
If a soil type is encountered whose properties differ substantially from those previously determined, then that soil type shall be treated as unsuitable material until the requirements of 7.1.1 have been fulfilled.

7.1.3
Soil types should be identified by the following soil classification tests where appropriate:

(a) For soils containing 15 % or less of silts and clays, particle size distribution tests complying with 11.6;

(b) Liquid limit tests complying with 11.3;

(c) Plastic limit determination complying with 11.4;

(d) Plasticity index tests complying with 11.5; and

(e) Special tests for soil such as loess and volcanic ashes may be used.

7.2
Mixing of soil types

7.2.1
Mixtures of soil types arise from normal earthmoving operations. To exercise full control of compaction, tests will be necessary to establish water content/dry density curves for the actual mixtures of soils obtained.

7.3
Soil water content during compaction

7.3.1
General

7.3.1.1
The limits selected for water content during compaction should be such as to ensure that the specified degree of compaction can be achieved.

7.3.1.2
Water content tests shall comply with either 11.1 or 11.2.

7.3.2
Cohesionless granular soils

7.3.2.1
For cohesionless granular soils where not more than 15 % by weight of the material passes a 75 μm standard test sieve, no quantitative water content limits need be given if tests show that there is not a defined optimum water content for maximum density.

7.3.2.2
The water content after compaction should not be so high as to allow the fill to weave under the weight of the compacting equipment.

7.3.2.3
Soils with soft grains (for example, pumice), and with particular gradings, may exhibit an optimum water content although the silt content is low.

7.3.3
Cohesive soils

7.3.3.1
For fills which contain sufficient clay or silt for the compacted soil to be cohesive in nature, water content limits shall be set in accordance with the type of uniform fill or mixed fill material being placed, and for the type of compaction plant in use.

7.3.3.2
The water content limits should be between 4 % below and 2 % above optimum moisture content; or alternatively detailed laboratory testing or full scale field trial compaction or both, shall be undertaken to establish water content limits within which the fill can be compacted to a satisfactory density and shear strength.

7.4
Compaction achieved

7.4.1
General

7.4.1.1
The measure of compaction achieved shall be one of the following:

(a) The dry density of the compacted soil established by tests complying with 11.7. Dry density shall be related to the maximum dry density established by the test specified in 11.8;

(b) For cohesionless soils, either the maximum dry density established by the test specified in 11.9 or the relative density determined from the maximum and minimum densities established by the test specified in 11.10;

(c) The relationship of specific gravity measured dry density and water content in the field to the percentage of air voids;

(d) The shear strength of the soil as measured with a hand vane and the air voids calculated from density and water content measurements;

(e) An alternative rational means which satisfies the requirements of the inspecting engineer.

7.4.1.2
The dry density or the air voids content of the compacted soil at any test site shall be taken as the mean of the results of two or more individual tests made within an area of 0.5 m² that has been carefully trimmed to below the compacted surface.

7.4.1.3
The dry density of the compacted fill at any one test site shall be not more than 5 % below the specified minimum.

7.4.1.4
The air voids content of the compacted fill at any one test site shall be not more than 2 % above the specified maximum.

7.4.1.5
The average of the dry densities of the compacted fill at any ten consecutive test sites shall be not less than the specified minimum.

7.4.1.6
The average of the air voids in the compacted fill at any ten consecutive test sites shall be not more than the specified maximum.

7.4.2
Cohesive soils

7.4.2.1
For cohesive soils the required minimum dry density of the compacted fill shall be as specified by the inspecting engineer. For many cohesive soils it is found that an acceptable minimum dry density for earth fill for residential development is 95 % of the maximum dry density as established by tests specified in 11.8. For highly plastic clays a slightly

lower minimum dry density may be specified by the inspecting engineer to reduce post-construction swelling of the bulk fill.

7.4.2.2
In reserve areas and other areas not required to support buildings or surfaces the inspecting engineer may specify a lower minimum dry density than for the remainder of the earth fill. Such low density fills shall be defined on "as-built" drawings.

7.4.2.3
An alternative method of compaction control for cohesive fills shall be to specify a minimum shear strength and a maximum air voids. These limits respectively prevent the soil from being placed too wet or too dry, and ensure that it is compacted to a dense, high strength state. This method is suitable for all cohesive soils, but has special advantages in situations where substantial and irregular changes in soil properties occur. In contrast to a density control method, where the specified density will vary with soil changes, this method uses specified properties which are independent of changes in soil type.

7.4.2.4
For many cohesive soils it is found that an acceptable minimum shear strength is 150 kPa and a maximum air voids is 10 %. For particular soil types, and for reserve areas or road subgrades, some variations from the above values may be appropriate.

7.4.2.5
Another approach to density control for cohesive fills shall be to ensure that the percentage of air voids in the compacted fill is less than a percentage determined by laboratory testing. A moisture content range (see 7.3) shall be specified in conjunction with the specified maximum percentage of air voids. This moisture content range will usually be related to optimum moisture content, but control testing is simplified if the moisture content range can instead be related to the plastic limit for a particular soil type.

7.4.2.6
As well as these minimum requirements of dry density, steps should be taken to ensure that cohesive fill is not too wet and over-compacted to an extent that weaving of the fill results.

7.4.3
Cohesionless soils

7.4.3.1
Where he considers it to be appropriate the inspecting engineer may use the same criteria for compaction achieved as given in 7.4.2 except that measurement of shear strength using a vane test is not suitable for cohesionless soils. Alternatively one of the following tests of NZS 4402 may be considered:

In situ CBR test .... Test 6.1.3
Dynamic cone penetrometer test .... Test 6.5.2
Static cone penetrometer tes .... Test 6.5.3

7.4.3.2
For many cohesionless soils the maximum dry density as established by tests specified in 11.8 may be considerably less than the dry densities that can be easily achieved by field compaction equipment. Two alternative approaches are available:

(a) The minimum and maximum densities for the soil are established by tests specified in 11.10, and the dry density of the compacted fill is expressed as a relative density in terms of these minimum and maximum densities. This relative density should be not less than 80 %;

(b) The dry density of the compacted fill shall be not less than 92 % of the maximum dry density of the soil as determined by tests specified in 11.9.

7.5 Other criteria for compacted soil

7.5.1
If the inspecting engineer specifies other criteria in addition to dry density and moisture content (see 7.1.1), the methods of test for the relevant properties shall be as specified by the inspecting engineer, who shall carry out a laboratory investigation on particular soil types to relate the soil property measured by such tests to the *in situ* density or moisture content of the fill.

7.5.2
The inspecting engineer shall establish and specify for each criterion tolerances similar to the tolerances for dry density and air voids, content as set out in 7.4.1.

8 CONSTRUCTION PROCEDURES

8.1 Planning

8.1.1
Earth fill operations should be planned to be carried out in a systematic manner, whereby areas of cut and fill are clearly defined before work commences, thus permitting effective control of the work.

8.2 Site preparation

8.2.1
Stripping

8.2.1.1
The area on which the fill is to be placed and the area from which the cut is to be removed shall be stripped of all vegetation and topsoil, and of such

soft or organic soils as may be determined by the inspecting engineer to be unsuitable. Special care should be taken to ensure that unstable organic materials are not overlooked in the foundation of fills through their being overlaid by other soils, either through man-made or natural causes.

8.2.1.2
Stripping should be carried out as a specific operation, with areas being stripped in large enough increments to ensure that there is an adequate margin of stripped ground beyond any current cutting or filling operation.

8.2.1.3
Topsoil stripped from areas being worked should preferably be placed directly to areas which are to be resoiled (see 8.5). Where this is impracticable, topsoil should be stock piled in locations where there is no possibility of the material being unintentionally covered over or incorporated into structural fills.

8.2.1.4
All other stripped material should be deposited in temporary stockpiles or permanent dumps in locations where there is no possibility of the material being unintentionally covered by, or incorporated in, structural fills.

8.2.2
Slope preparation

8.2.2.1
Where a fill abuts against sloping ground, benches should be cut in the ground to prevent the development of a continuous surface of low shear strength.

8.2.3
Foundation compaction

8.2.3.1
Before fill is placed on the stripped natural ground the ground surface should be smoothed and compacted in a manner similar to that to be used on the layers of fill, unless a specific decision has been made to cover soft natural ground with fill.

8.3
Fill construction

8.3.1
Fill placing

8.3.1.1
The quality of fill material and control tests to check this shall be determined and specified before fill placing commences (see section 7).

8.3.1.2
Fill shall be placed in a systematic manner, with near-horizontal layers of uniform thickness of material each being deposited progressively across the fill area.

8.3.1.3
The method of excavation, transport, and depositing of fill material shall be such as to ensure that the fill is as uniform a mixture as possible.

8.3.1.4
The thickness of each layer shall be limited to ensure that the bottom of each layer is adequately compacted. The uncompacted thickness of the layer shall be less than 230 mm unless it is shown by tests that satisfactory results can be obtained with thicker layers.

8.3.1.5
Before any loose layer of fill is compacted, the water content of the layer shall be as uniform as possible and the soil shall be free of lumps which exceed half the uncompacted layer in thickness.

8.3.1.6
Any compacted layer which has deteriorated after an interruption in the earthmoving operation shall be recompacted before any further layer is placed over it.

8.3.2
Fill water content control

8.3.2.1
Fill material shall be compacted only while the water content of the uncompacted material is within the specified range (see 7.3).

8.3.2.2
When the water content of uncompacted material falls below the specified minimum, the material should be watered either on the fill or in the cut before it is transported to the fill. Water should be applied as a fine spray in order to reduce non-uniform distribution.

8.3.2.3
When the water content of uncompacted material is non-uniform the material should be mixed.

8.3.2.4
When the water content of uncompacted material rises above the specified maximum, drying of the material may be accelerated by aeration. If this is done by blading, special care is needed to ensure that this method of working does not produce segregation of the material.

8.3.2.5
Control of water content shall be applied not only to the upper layer of uncompacted material but also to the loose surface material of the previously compacted layer. This surface material shall be brought to the correct water content before it is

covered by a new layer.

8.3.2.6
In addition to regular control tests to determine the water content of the material being compacted, continual visual and non-quantitative soil-consistency checks shall be made by experienced responsible personnel to prevent material being compacted when its water content has deviated from the specified limits.

8.3.3
Fill compaction

8.3.3.1
Each layer shall be compacted as a specific construction operation, using plant specifically assigned to the compaction task and following systematic patterns of travel tracks which progressively work across the surface of the fill.

8.3.3.2
The type of compaction plant used should be selected so that it consistently achieves the specified standard of compaction. Compaction plant should be of a type which can travel close enough to the junction of the fill and natural ground to ensure effective compaction over the entire area of the fill. The compaction plant should be separate from that used for earth-moving, except in special circumstances where the earthmoving plant can be adapted for compaction to the satisfaction of the inspecting engineer.

8.3.3.3
Fill batter faces should be compacted as a separate operation, or alternatively overfilled and cut back.

8.3.3.4
Where density testing shows the fill compaction to be below the specified minimum, all material represented by the test shall be further compacted to exceed the minimum compaction requirements as confirmed by further testing, or shall be removed and recompacted.

8.3.4
Surface weaving

8.3.4.1
Surface weaving is characterized by the pronounced elastic compression of the surface of the fill and an immediate rebound during the passage of heavy wheeled plant. It is considered to be the manifestation of development of shear instability in areas where overcompaction has contributed to the material's approaching full saturation.

8.3.4.2
In areas of fill where excessive surface weaving has developed, *in situ* density and water content tests shall be made.

8.3.4.3
The development of surface weaving on fills should be avoided by:

(a) Ensuring that the water content of material being placed is kept below the specified maximum;

(b) Providing drainage on the surface of the fill and preventing accumulation of surface water in puddles;

(c) Routing of heavy earthmoving plant to prevent excessive compaction of materials having relatively high water content; and

(d) Providing drainage layers within the fill to dissipate excess pore pressures.

8.3.5
Freezing

8.3.5.1
When the surface material of the fill is frozen, neither compaction nor filling operations shall take place on the affected areas.

8.4
Temporary drainage and erosion control

8.4.1
The control of silt from development works may be subject to a water right in terms of the Water and Soil Conservation Act 1967. During the construction period measures shall be taken to prevent fill material from being eroded and redeposited at lower levels where it might cause damage to property, malfunctioning of drainage systems, public nuisance or danger.

8.4.2
During the construction period, measures shall be taken to prevent excessive waterlogging of surface materials yet to be excavated or compacted, or both.

8.4.3
Without prejudice to the conditions of any water right, the following practices should be adopted:

(a) The surfaces of fills and cuts should be graded to prevent ponding;

(b) The upper surfaces of fills should be compacted with rubber tyred or smooth-wheeled plant when rain is impending, or when the site is to be left unattended;

(c) The completed battered surfaces of fills should be compacted with sheepsfoot or similar non-smooth compaction plant to reduce run-off velocities;

(d) Surface water should be prevented from discharging over batter faces by drains or ditches formed to intercept surface run-off and to discharge via stable channels or pipes, preferably into stable water courses or piped stormwater systems as approved by the local authority;

(e) Silt-traps of adequate capacity should be constructed to pond run-off and precipitate silt so that it is prevented from being washed down to where it could cause damage.

8.5
Revegetation

8.5.1
Earth fills should be left in a condition which facilitates their vegetation. This requires a reasonable depth (minimum 300 mm) and quality of topsoil together with the scarifying of the surface of the fill. A programme for establishing and maintaining vegetative cover should be drawn up as part of the design of the fill.

8.5.2
The type of vegetative cover and the list of species should relate to the end use of the fill and should be appropriate to the area concerned. (Ref. *Revegetation*, Queen Elizabeth II National Trust.)

9
INSPECTION AND CONTROL OF QUALITY

9.1
General

9.1.1
The inspecting engineer shall ensure an adequate level of quality control, supervision, and testing to enable him to evaluate properly the general quality of the finished work, and to enable him to furnish a report as to the compliance of the work with this Standard. This is not to be construed as a guarantee or warranty but rather as a record of reasonable professional care.

9.2
Inspection

9.2.1
Visual inspection of the quality of earth fills shall be made by the inspecting engineer, or a competent inspector acting on his behalf, at the following times:

(a) After any part of the existing ground has been finally stripped and prepared and before the placing of any fill on that ground;

(b) After any drain has been installed and before that drain is covered by a fill; and

(c) At such other times as the inspecting engineer considers necessary to enable him to assess the general standard of the filling material and its compaction and to reasonably satisfy himself that:

(i) No fill is placed over soft or organic foundation material without the specific authority of the inspecting engineer;

(ii) No unsuitable materials are used as fill;

(iii) Water content control during compaction appears, on visual inspection and non-quantitative soil consistency checking, to be consistently within the specified range;

(iv) Compaction operations are systematic and the degree of compaction appears to be consistently satisfactory; and

(v) All areas of existing ground showing seepage or potential seepage emission have relief drains provided.

9.3
Control testing for fills

9.3.1
Types of tests

9.3.1.1
During the construction of earth fills the following quantitative control tests should be made on the fill material:

(a) Soil classification tests to assess the degree of uniformity of fill materials and to relate the fill material to one of the soil types for which compaction properties have been established as required by 7.1; or suitable tests to determine the maximum dry density for the soil tested in each *in situ* field density test;

(b) Water content tests to determine whether the water content is within the specified limits;

(c) *In situ* density tests to determine whether the degree of compaction is up to the specified minimum;

(d) Hand vane shear strength measurements in those cases where a shear strength and air voids control method is being used; and

(e) Such other tests as may be specified by the inspecting engineer for control testing of fills of particular soil types, provided that the soil property tested shall be related to *in situ* density or water content of the fill by a laboratory investigation. Such tests include shear strength tests, cone penetrometer tests, and Proctor needle tests.

9.3.1.2
Methods of test shall comply with those specified in section 11.

9.3.2
Frequency of tests

9.3.2.1
Once the filling work is progressing as a steady operation with uniform construction methods and uniform material conditions, and provided that:

(a) Adequate visual inspection is being maintained;

(b) Adequate construction effort is being maintained; and

(c) The requirements of this Standard are being met, then the minimum frequency of control testing subject to 9.3.2.2 shall be:

(i) Soil classification tests:
One set of tests as specified by the inspecting engineer for each distinguishable soil type used.

(ii) Water content tests:
Wherever there is doubt that the water content of the uncompacted material is within the specified limits.

(iii) *In situ* density tests:
For each 4000 m^3, or 1.5 m lift of fill, one set of tests (see 11.7) or as specified by the inspecting engineer for each distinguishable soil type used; and

(iv) Other tests:
Frequency to be specified by the inspecting engineer.

9.3.2.2
Testing shall be more frequent than is specified by 9.3.2.1 under any of the following circumstances:

(a) During the first 4000 m^3 of filling carried out on the project;

(b) On the final layer of not less than 1.5 m depth where the minimum frequency of *in situ* density tests shall be three sets of tests for each 3000 m^2;

(c) When soil type or conditions are variable;

(d) When the inspecting engineer or his inspector is in any doubt about the adequacy of construction methods or about any of the soil properties;

(e) When a decision to reject work, based on the judgment of the inspecting engineer or his inspector, is disputed; and

(f) When relatively small quantities of fill are concentrated in localized areas, or placed discontinuously over a long period of time.

9.3.3
Selection of test sites or samples

9.3.3.1
Material sampled for water content control tests shall be taken from the spread layer immediately before, during, or immediately after compaction. The location of the sampling shall be determined by the inspecting engineer or his inspector. Sample location should be chosen so as to test material likely to be furthest from the specified quality.

9.3.3.2
In situ density test locations on the completed layer of the fill shall be decided by the inspecting engineer or his inspector, who should select an area or areas likely to yield the lowest values of *in situ* dry density.

9.3.4
Reporting test results

9.3.4.1
Results of quantitative control tests should be reported in writing to the inspecting engineer and to the construction agencies immediately they are completed. For economical construction it is essential that results of control tests be supplied expeditiously.

9.3.4.2
All field and laboratory test data shall be recorded in a systematic manner that will allow the results to be identified and allow the calculations to be checked at a later date if necessary.

9.3.4.3
All control test results shall have recorded the time, date, and approximate location of sampling in the fill.

9.3.4.4
Test results relating to sections of fill that have been subsequently removed or reworked and recompacted should be noted accordingly.

9.4
Final performance measurements

9.4.1
On completion of the earthworks and before any building construction commences, permanent levelling points should be set in the upper surface of any fill which is in excess of 10 m in vertical depth.

9.4.2
For each levelling point there should be provided nearby a reference bench mark on stable natural ground. This may require sleeved columns to depths of 3 m or more in clays susceptible to

seasonal volume changes.

9.4.3
Sufficient levelling points should be provided to result in good indication being obtained of the pattern of settlement within the entire fill.

9.4.4
The locations and relative levels of levelling points on fills and benchmarks should be measured and recorded, with the date of levelling on the as-built drawing.

10 FINAL DOCUMENTATION

10.1 As-built drawings

10.1.1
On completion of the earthworks an as-built contour plan shall be compiled so that the final topography can be related to the original topography of the subdivision. Areas of filled ground and associated drainage shall be clearly indicated on this plan. The as-built plan should also record the locations and levels of the levelling reference points (see 9.4) and it should delineate areas of filling of low density and any fill areas considered by the inspecting engineer as not complying with this Standard. On completion of earth fill construction, copies of the as-built drawings shall be made available by the owner of the land, to the local authority.

10.2 Inspecting engineer's report

10.2.1
On the successful completion of construction the inspecting engineer shall furnish to the owner of the land at the time of the construction of the earth fill, a report describing the extent of the inspection, the results of testing, and his professional opinion as to the compliance of filled ground in the subdivision to this Standard.

10.2.2
The owner/developer shall submit to the local authority, his statement of suitability for residential development for all lots within the subdivision that contain filled ground.

10.2.3
The statement should be supported by the opinion of the inspecting engineer as to any special limitations to be observed. A recommended form of statement is shown in Appendix A.

11 TEST METHODS

11.1 Water content, standard method

11.1.1
Tests for water content by this method shall comply with NZS 4402, Test 2.1.

11.2 Water content, rapid methods

11.2.1
Various methods are available for the rapid determination of water content of a soil which is expressed as:

$$\frac{\text{Mass of water in sample}}{\text{Mass of dry soil in sample}}$$

Most methods are described in U.S. Highway Research Board Bulletin 272, *Factors that influence field compaction of soil.* An effective rapid method is the nuclear method measuring neutron diffraction. Rapid methods of water content determination are not always reliable and should be checked against NZS 4402, Test 2.1 for the particular type of soil used in the fill.

11.3 Liquid limit

11.3.1
Tests for liquid limit shall comply with NZS 4402, Test 2.2 except that the soil water content shall be adjusted directly from the natural water content to the test water content without prior drying.

11.4 Plastic limit

11.4.1
Tests for plastic limit shall comply with NZS 4402, Test 2.3, except that the soil water content shall be adjusted directly from the natural water content to the test water content without prior drying.

11.5 Plasticity index

11.5.1
Determination of plasticity index shall comply with NZS 4402, Test 2.4.

11.6 Particle size distribution

11.6.1
Tests for particle size distribution of soil shall comply with NZS 4402, Test 2.8.1, 2.8.2, 2.8.3, or 2.8.4 as appropriate.

11.7
In situ density

11.7.1
Tests for *in situ* density shall comply with NZS 4402, Test 5.1.1, 5.1.2, 5.1.3, 5.1.4 or 5.1.5, provided that the inspecting engineer may specify alternative test methods such as nuclear gauge methods.

11.7.2
Where the material contains stones exceeding 20 mm in size, the mass and volume of these stones should be excluded from the density determination. Special measures may be required if the plus 20 mm content exceeds 30 %.

11.8
Density/water content relation (standard compaction test)

11.8.1
Tests for density/water content relation shall comply with NZS 4402, Test 4.1.1, except that the soil water content shall be adjusted directly from the material water content to the compaction water content without prior drying.

11.9
Density and water content relation (vibrating hammer method)

11.9.1
Vibrating hammer tests for density and water content relation when used on cohesionless soils shall comply with NZS 4402, Test 4.1.3.

11.10
Relative density test

11.10.1
Minimum and maximum dry density tests and relative density tests, when used on cohesionless soils, shall comply with NZS 4402, Tests 4.2.1, 4.2.2 and 4.2.3.

11.11
Solid density

11.11.1
Tests for the determination of solid density of particles of a soil shall comply with NZS 4402, Test 2.7.1 or 2.7.2 as appropriate.

11.12
Shear strength

11.12.1
Tests for the determination of the shear strength of cohesive soils shall comply with NZS 4402, Test 6.4.2. Alternatively another method approved by the inspecting engineer may be used.

APPENDIX A

STATEMENT OF SUITABILITY OF EARTH FILL
FOR RESIDENTIAL DEVELOPMENT

To ....(name and address

....of Local Authority)

....

STATEMENT OF SUITABILITY OF EARTH FILL FOR RESIDENTIAL DEVELOPMENT

Subdivision ....

Owner/Developer ....

Location ....

The earth fills shown on the attached plan No. .... have been placed in compliance with the terms of NZS 4431.

While work was in progress I retained as my inspecting engineer the engineer named below who is registered in terms of the Engineers Registration Act 1924.

....

Address ....

During the work, the inspecting engineer and his staff made periodic visits of inspection to the site as detailed in his report No. .... which is attached. Details of the soil testing carried out to check the quality of the fill by the inspecting engineer and his testing agency are also included in this report.

The attached plan No. ....shows Lot Nos.

....

to be affected by filling and the extent of the fill.

In the opinion of the inspecting engineer the following special limitations should be observed:

....

....

This certification, that the earth fills have been placed in compliance with the terms of NZS 4431 does not remove the necessity for the normal inspection and design of foundations as would be made in natural ground.

....(signature)

....(position)

....(date)

on behalf of ....

....

....

....(name of Owner/Developer)

NOTES

Code of practice for
EARTH FILL FOR RESIDENTIAL DEVELOPMENT

Pr Gratis

AMENDMENT No. 1

July 1992

EXPLANATORY NOTE – This Amendment applies when this Standard is used as a Verification Method that is referenced in Approved Document B1 Structure – General, to the New Zealand Building Code. The Amendment need not apply when this Standard is used under the Model Building Bylaw system which remains in operation until 31 December 1992.

To ensure receiving advice of the next amendment to NZS 4431:1989 please complete and return the amendment request form.

APPROVAL

Amendment No. 1 was approved in July 1992 by the Standards Council to be an amendment to NZS 4431:1989 pursuant to the provisions of section 10 of the Standards Act 1988.

(Amendment No. 1, July 1992)

1.1 and **1.2**
Delete the clauses and **substitute** the following:

"**1.1**
This Standard provides methods for the design and control of earth fill construction. Experience has shown these methods provide satisfactory foundation stability for buildings constructed in accordance with NZS 3604 and NZS 4229. The same methods are also adequate for ensuring satisfactory stability for residential services and streetworks.

1.2
The effectiveness of this Standard is dependent upon the Inspecting Engineer's advice being followed.

1.3
This Standard is cited as a Verification Method in Approved Document B1 Structure - General to the New Zealand Building Code."

(Amendment No. 1, July 1992)

1.3
Re-number the clause "1.4".

(Amendment No. 1, July 1992)

3.1
Delete the definition of "INSPECTING ENGINEER" and **substitute:**

"INSPECTING ENGINEER means any person who on the basis of experience or qualifications, is competent to design and supervise earth fill construction, and who at the time of construction, signs and submits to the owner, a report confirming whether or not the fill complies with this Standard".

(Amendment No. 1, July 1992)

4.1.1
Delete the introductory sentence and **substitute:**

"Where any proposed subdivision involves the construction of earth fills on any part of a proposed housing lot, then an inspecting engineer, as defined in section 3, shall be engaged. The inspecting engineer shall specify the relevant compaction standards to be achieved, the test methods, and the construction practices to be used, and shall carry out the following functions:"

(Amendment No. 1, July 1992)

6.1.1.3
In line 3 **delete** "NZS 1900" and **substitute** "NZS 3604 and NZS 4229".

(Amendment No. 1, July 1992)

6.2 and **6.3**
Delete the clauses.

NOTE – These clauses provide useful information relating to good practice, but are not essential to the use of the Standard as a Verification Method to NZBC B1.

(Amendment No. 1, July 1992)